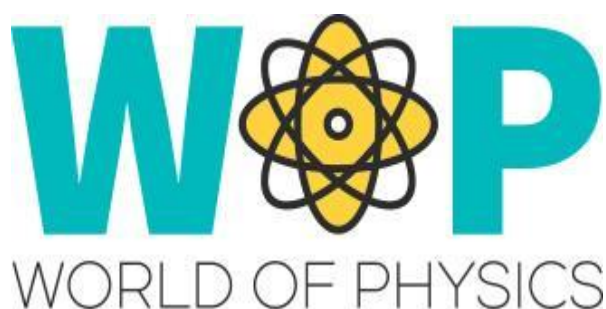


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Deliverable Number **Report II**

Deliverable Title **Applications of ICT in Physics Education**

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Partners



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Executive Summary

Research on the utilization of ICT in physics education is deemed very important for the work to be conducted in the scope of the World-of-Physics project. The aim of the report is to provide an overview of the technologies and their use in the context of physics courses in schools. Both theoretical aspects and application cases are examined and presented in this study.

List of abbreviations

Abbreviation	Definition
ITS	Intelligent Tutoring Systems
CAI	Computer-Assisted Instruction
ICT	Information & Communication Technology
VRML	Virtual Reality Modelling Language
VR	Virtual Reality
OECD	Organisation for Economic Co-operation and Development

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1. Introduction

Over the last years, the necessity and the effects of technology in every-day human lives are undeniable. Indeed, in today's dynamic and constant changing world, life without technology seems to a great degree to be meaningless. The concept of Technology mainly refers to bringing together tools that ease creation, use and exchange of information and has a main aim in making tasks easier to execute as well as solving many mankind's problems. Information & Communication Technology (ICT) is considered to be the technology used in order to store, transfer and process information, where information can be used to define one or more pieces of ideas or perceptions. Also, technology can refer to the means by which a person, an organization or the society does important and necessary procedures. In this line, information and technology can each range from being very simple to very complex and some indicative examples of Information & communication technology are writings, printed text, photographs, radio, motion pictures, sound recordings, television, and most of all computers. With the constant advancement of technology, there is a need to point out how useful it has been to several topics of everyday lives. A fundamental domain where the advancement of technology has great impact is the domain of education.



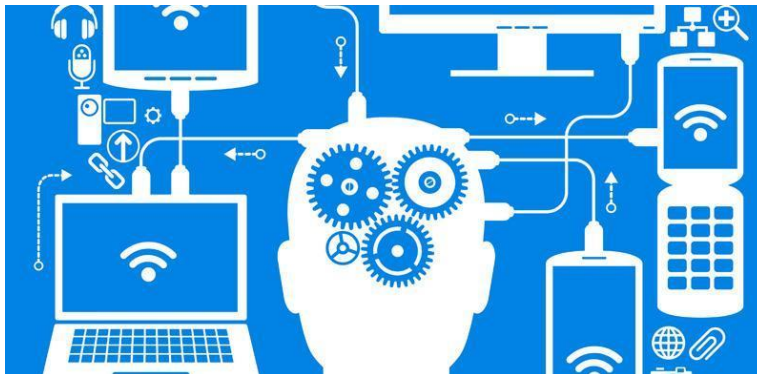
2. Importance of ICT in Physics education

2.1. Introduction

The domains of education, training and learning are considered to be lifelong procedures, which have no clear limits on when to start and stop. ICT has the ability of greatly speeding up information delivery, so this ability can be used in improving the efficiency of educational procedures in learning environments. With the implementation of advanced and state of the art ICT, costs of accessing educational material and procedures are cut down and it makes it easy for students to learn anytime from anywhere.

ICTs offer new ways of structuring the courses curriculum to both support student inquiry and also to cover a wider spectrum of content. A major commitment to using technological tools in the context of courses curriculum is to permit more advanced mathematics and science concepts to be treated. In addition, with the advancement of technology, computational power frees mathematics students to explore both mathematical and real-world phenomena where in the past the computational complexity would have been a great barrier. With this power available,

students have the opportunity to investigate and understand topics that are beyond the current curriculum standards.



2.2. Benefits

There are many benefits integrating Information and Communication Technology in Education. According to Karehka Ramey [1] the benefits can be found in the following topics:

- **Plenty of Educational Resources:** ICT makes easier for students to access academic information from anywhere and at any time they want. All the students and teachers can use ICT in order to access and also to exchange learning content and educational material. This breaks the boundaries of accessing information, because the student will simply attend a lecture while not in a physical classroom of the real world. Also teachers can assign tasks to students via electronic means.
- **Instant Access to Educational Information:** ICT can speed the transfer and distribution of information. Students can easily access academic data using computers and new advance technologies like mobile phone application. These mobile phone applications are replacing some old methods like books

in libraries. Nowadays students can use Library mobile phone apps in order to download e-books, so they have these books at any time which saves them time and helps them read at any time they want from anywhere.

- **Full Time learning:** In the past, learning was limited to physical classroom where students and teachers could only access academic information while they were at school. Today, all that has greatly changed. All the students can access information at any given time of the day.
- **Group Learning:** ICT has helped students learn in groups and it has also helped teachers teach students in groups. Students from various schools around the world can be in the same academic group and share academic information.
- **Use of Audio – Visual:** ICT has greatly changed the way we learn and interpret information. The use of audio-visual education can assist students in learning faster and easier. Visual illustration using images on projectors can help a student understand the concept, because some of these images are interesting and they look familiar to students.
- **Long Distance learning:** ICT enables students across the globe to study from anywhere, anytime through online education. This is possible mainly due to the wide spread of cheap broadband internet. Unlike in the past, when some courses used to be provided in developed countries, so for a student to study those courses they had to go through the hassle of moving from their home country which was very expensive. Now days, a student can have access to these courses online.

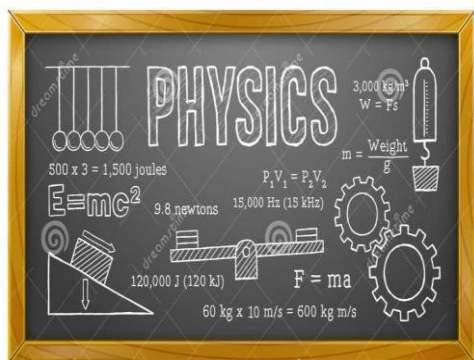
but doing them better or to a higher level of student comprehension.

- **Addition.** Technology makes it possible to achieve new curriculum goals, by adding new, additional material to existing courses. As an example consider the TERC Global Lab project which was developed in the context to facilitate the addition to existing science courses the possibility of international collaboration and peer review simply by creating schools groups which are linked through means telecommunications technology.
- **Disciplinary restructuring.** The capacity of ICTs offers opportunities to redesign courses or series of courses within a discipline. For instance, graphing procedures can be introduced far earlier in math sequence, giving to students skills that can help their understanding of concepts.
- **Interdisciplinary restructuring.** Technology can support the redesign of courses across disciplines. For instance, if systems modeling were learned in ninth grade math, then subsequent science courses could use this capacity to address a broader range of science material at a deeper level.

3.3. Different Ways of Using ICT

The utilization and integration of ICTs into educational procedures can benefit both students' learning and teachers' teaching and is of utmost importance for teachers in performing their role as creators of pedagogical procedures. There is a wide spectrum of means and ways that ICT can be used and assist in education and in better studying and learning the physics domain. They can range from simply using

ICTs as tools to support traditional ways of teaching or even to fully ICT-enabled courses that entail a completely different way of teaching [3]. The Organisation for Economic Co-



operation and Development (OECD) (2005) distinguishes four different levels, depending on how prominent the ICT / eLearning tools are in courses [3]:

- Web-supplemented courses focus on classroom-based teaching but include elements such as putting a course outline and lecture notes online, use of e-mail and links to online resources.
- Web-dependent courses require students to use the Internet for key elements of the programme such as online discussions, assessment, or online project/collaborative work, but without significant reduction in classroom time.
- In mixed mode courses, the e-learning element begins to replace classroom time. Online discussions, assessment, or project/collaborative work replace some face-to-face teaching and learning. But significant campus attendance remains part of the mix.
- In fully online courses, students can follow courses offered by a university in one city from another town, country or time zone. The types of e-learning offered by universities range right across the e-learning spectrum, but in most campus-based institutions, the growth of e-learning has not altered the fact that face-to-face classroom teaching remains central

In the following subsections, the main utilization ways are examined and presented.

3.3.1. Simulations

Simulations have been probably the most important and wide spread field. In this line, many software applications and computer games can be considered to be to some degree simulations. Also, there are programs which have won the contest organized by the journal "Computers in Physics" [4], such as the program Interactive Physics [5], a popular simulation tool published by Knowledge Revolution. The simulations can allow students to make abstract ideas concrete. More specifically, students gain insight into various concepts by watching in detail and thoroughly how they are conducted.

The laws of Physics are expressed in most cases by differential equations and it can be easy to implement a simulation for a given physical problem. For instance, it can be the free fall of an object, the orbital motion of planets, the collision of two



galaxies and many more. Simulations may also be made when we do not have a differential equation but we have to simulate to some degree an iterative relation.

Simulations are also very helpful in cases we have to examine and study the

nature of experiments which are very difficult or even impossible to conduct in practice for various reasons. These reasons can be for example the very high cost of the ingredients of an experiment or even possible dangers [6]. In the following figures, example simulation cases are presented.

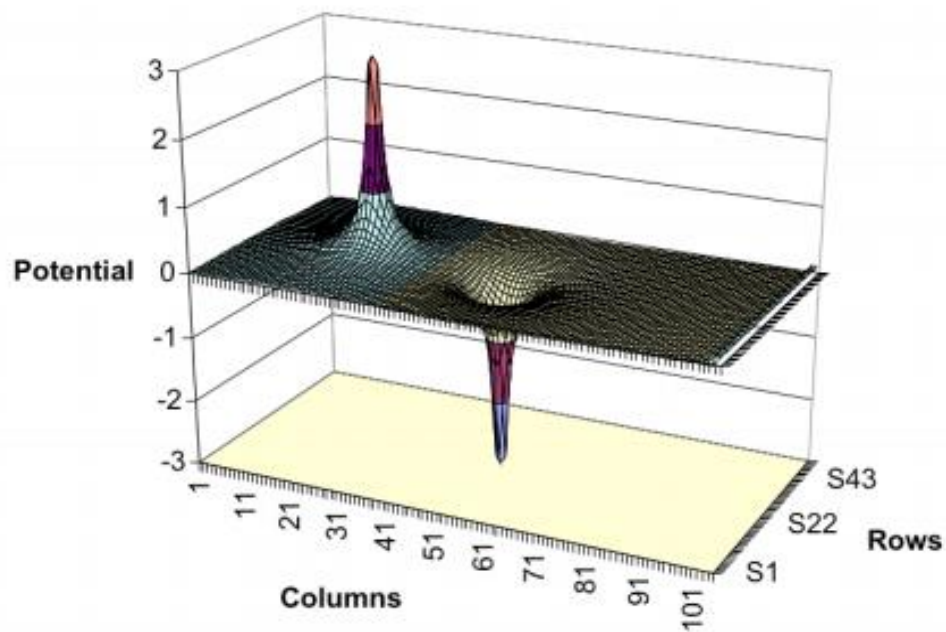


Figure 1: Potential around dipole

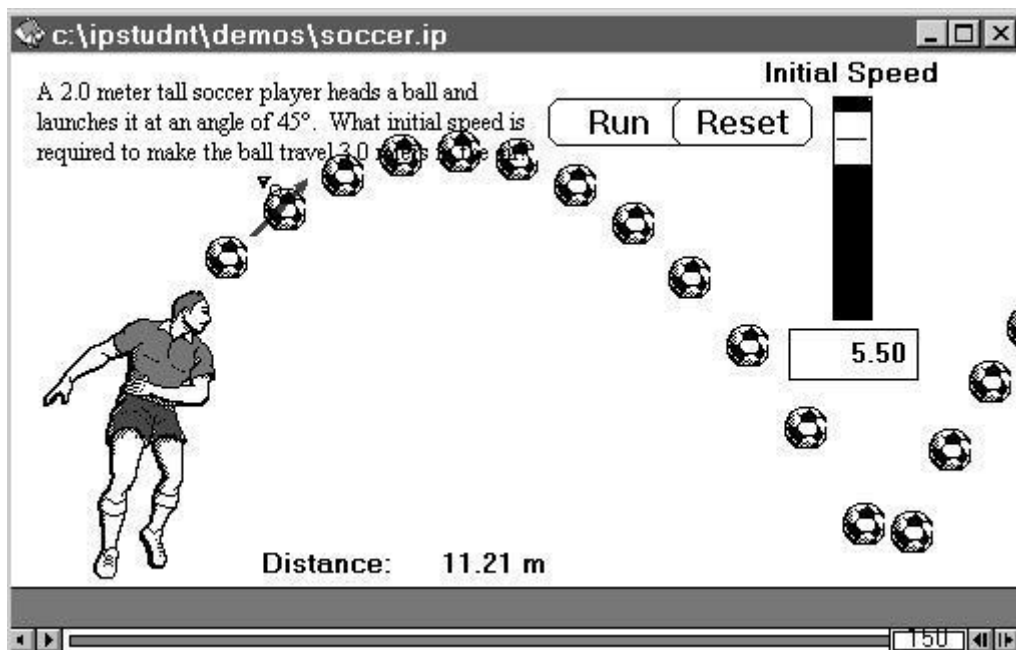


Figure 2: Simulations of movement

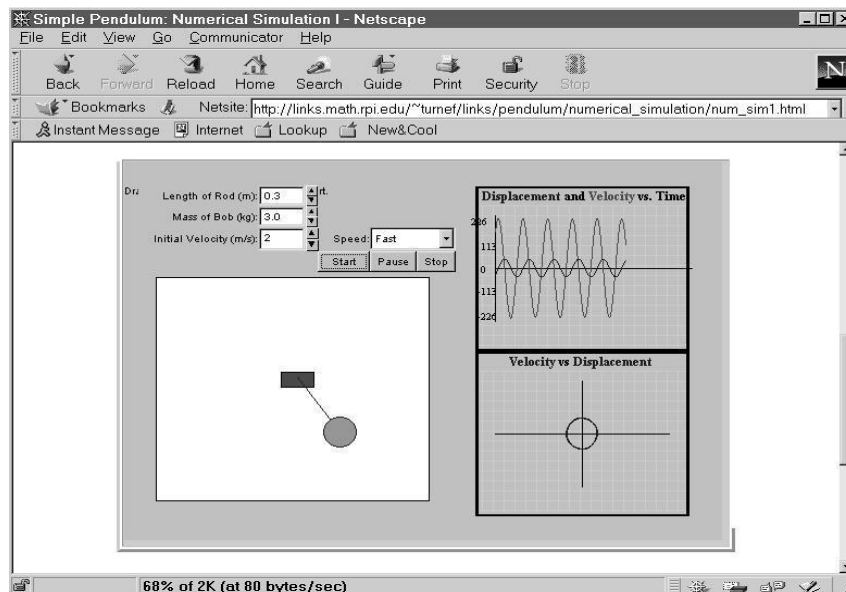


Figure 3: Simulation of motion of a simple pendulum


3.3.2. Multimedia

Multimedia contents are mainly based on the concept of hypertext and hypermedia. As the word 'multimedia' defines, contents can include a vast spectrum of elements, like text, images, animations, simulations video clips and many others. The well-known motto "an image is one thousand words worth" so that the information should be as visual as possible. In this context, Hypertext can have several internal links and a reader does not need to follow a linear or sequential path through the module but, based on his experience and interests, may easily select parts of module that are of greater interest to him. The most essential features of multimedia are interactivity and flexibility. Depending on the way they can be assessed by uses, multimedia can be online or offline based on the exact way that their information is offered.

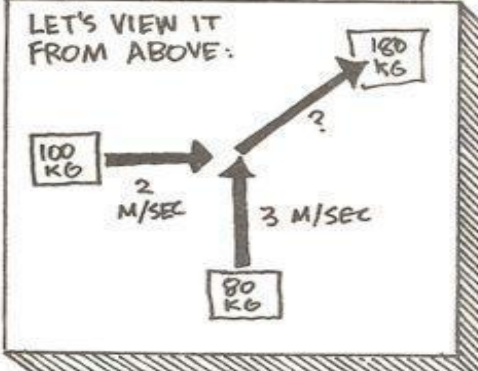


A popular and nice example of the use of multimedia in Physics is the Cartoon Guide to Physics [7]. It can be used in Physics classes and also extra class activities and it includes several interactive simulations. In the following figure, a simple textual example case of a problem of Cartoon Guide to Physics is illustrated.

HERE'S A 2-DIMENSIONAL EXAMPLE: AN 80-KG FOOTBALL PLAYER GOING NORTH AT 3 M/S IS TACKLED BY A 100-KG PLAYER GOING EAST AT 2 M/SEC. AFTER THE IMPACT, WHICH WAY ARE THEY GOING, AND HOW FAST?

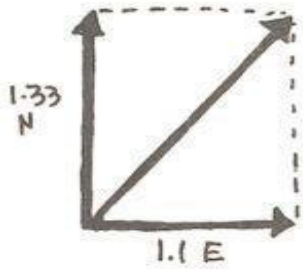


LET'S VIEW IT FROM ABOVE:



EASTWARD MOMENTUM = $200 \frac{\text{M} \cdot \text{KG}}{\text{SEC}}$
 NORTHWARD MOMENTUM = $240 \frac{\text{M} \cdot \text{KG}}{\text{SEC}}$
 TOTAL MASS = 180 kg
 SO:
 FINAL EAST-WARD VELOCITY = $\frac{200}{180} = 1.1 \text{ M/SEC}$
 FINAL NORTH-WARD VELOCITY = $\frac{240}{180} = 1.33 \text{ M/SEC}$

THE FINAL DIRECTION IS THE VECTOR SUM:



THE LENGTH OF THIS ARROW IS THE FINAL SPEED:

$$V_F = \sqrt{(1.1)^2 + (1.33)^2}$$

$$= 1.7 \text{ M/SEC.}$$

87

Figure 4: Cartoon Guide to Physics example

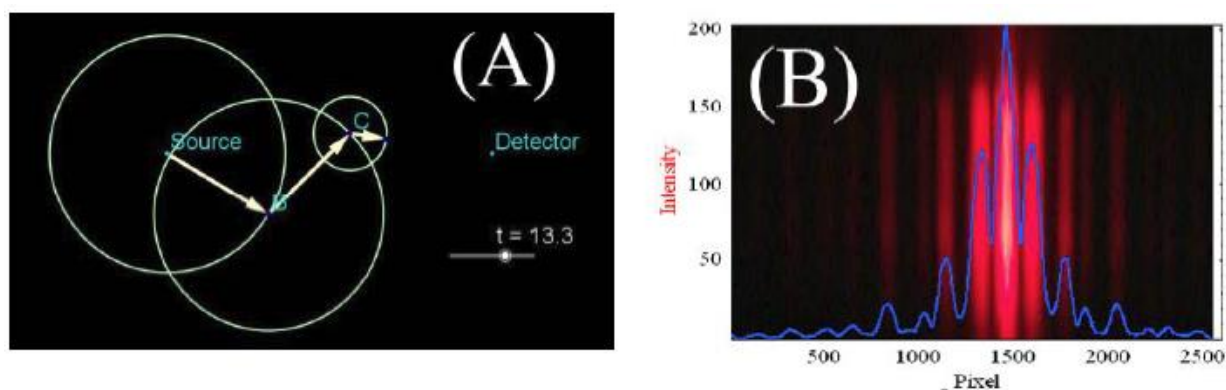


Figure 5: (A) Animation illustrating the connection between the Huygens- Fresnel [21] principle and the idea of using all possible optical paths from source to detector. (B) Two slit interference patterns with superimposed Tracker analysis of the light intensity

Computer games represent a very good and interesting way for students to study and learn basic aspects and procedures of physics domain. In many games and in various procedures, students may not always be aware that the game that they are interacting and playing with is using basic physics laws for game mechanics. Consequently, games can be used as a didactical tool to teach students physics and make physics lessons more interesting for them. There is a variety of games that can be used for experimental procedures.

A well-known and wide used game that is still very popular is the game Super Mario Bros which can be used with a problem-based approach for calculating basic kinematics and studying different problems within Mario world. In addition, a very interesting game for learning physics is also Scorched 3D. In this game, a player must set the power, angle, direction of a projectile to hit another tank while considering the wind affecting the projectile course. In this game, we can learn the physics of projectile motion and introduce it clearly to the students. Sometimes you have to fail in game to figure out how to complete the mission. A game that is made on this concept is called Angry Birds, where you use different birds as projectiles to destroy green pigs. We can use this game to teach various concepts in physics, for

example forces, Newton's law, collision and explosion [8].

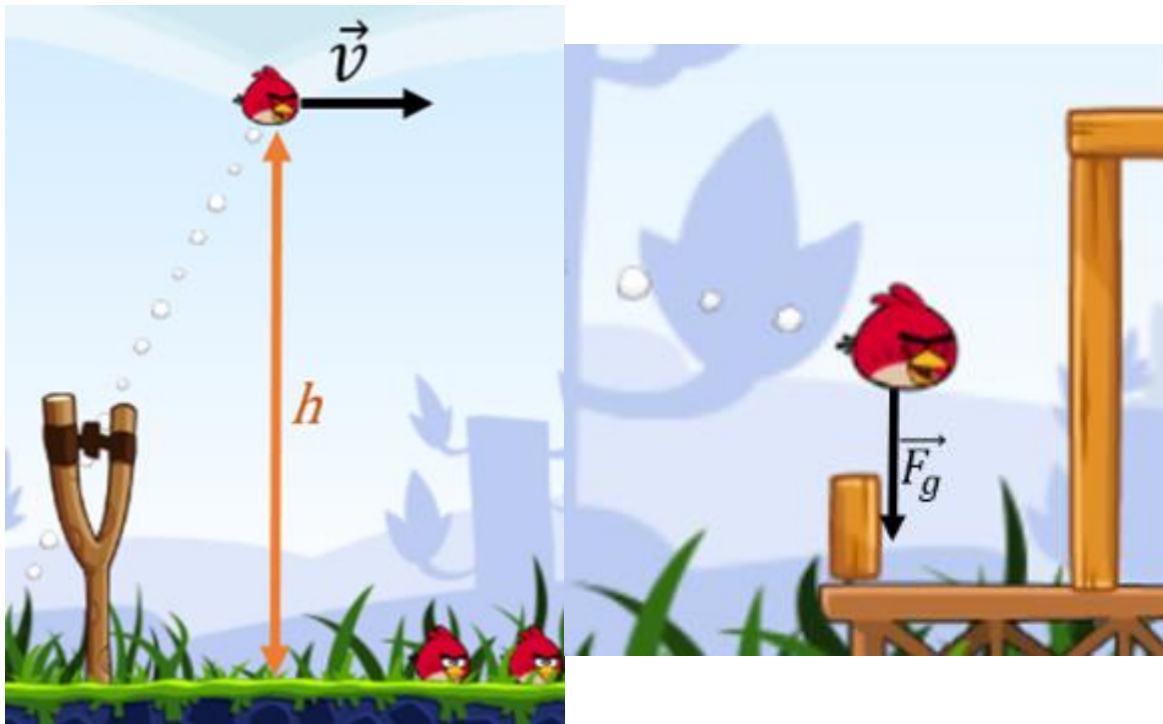


Figure 6: Newton's Law through Angry birds

3.3.3. Telematics

Telematics constitutes another aspect of technology that has great educational capabilities in physics education. Telematics mainly refers to a broad term that encompasses tools and technologies which are built by integrating telecommunications and information & communication technologies. With telematics, telecommunications and ICT can be used to formulate holistic communication systems via the ability to send, receive and process information between remote devices. In addition, Internet has a big success in wide aspects of the society and also in schools. Its use for science and in teaching and learning of physics domain has a big potential.



In most cases, in the globally prevailing class education model, the teacher usually plays the core role, determining the pace of students learning in class level. With the use and by taking advantage of the new technologies, more interactive and efficient

A main stream of the combination of telematics and virtual reality is the VRML (Virtual Reality Modelling Language). It is the standard for representing 3D objects or scenes on the Internet and can offer another possibility of using the Internet. It expands the standard HTML with the opportunity to visualize 3-dimensional scenarios and interact with various basic elements and constructions. In topics such as for example solid state physics, where the models need 3D representations, the new techniques can be applied naturally and very effectively to improve students understanding and knowledge construction. An example is the Geogebra system [9] for learning basic math, engineering and science topics as illustrated in next Figure.

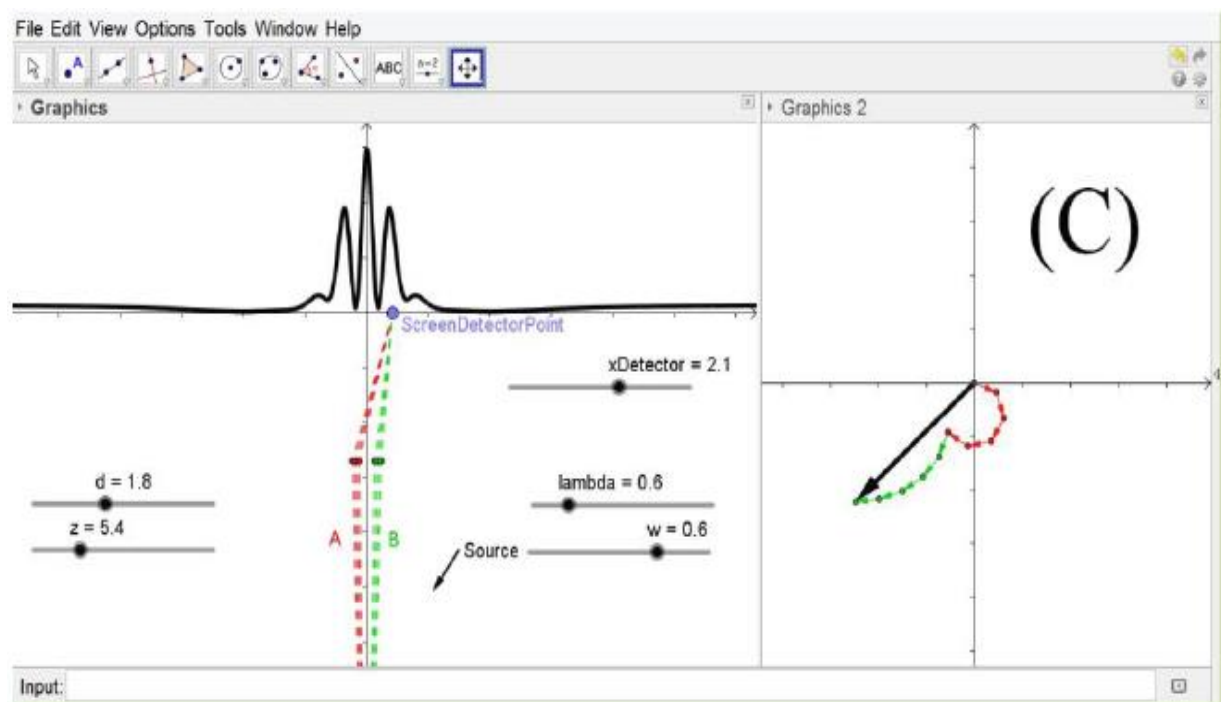


Figure 7: GeoGebra system illustration

3.3.4. Virtual Reality

Virtual reality (VR) typically refers to computer technologies that use software to



generate realistic images, sounds and other sensations that replicate a real environment (or create an imaginary setting), and simulate a user's physical presence in this environment, by enabling the user to interact with this space and any objects depicted therein using specialized display screens or projectors and other devices. VR has been

defined as "...a realistic and immersive simulation of a three-dimensional environment, created using interactive software and hardware, and experienced or controlled by movement of the body or as an "immersive, interactive experience generated by a computer [10]. Virtual reality is considered to be artificial environments created with software and presented to the end user in such a way that the user suspends belief and accepts it as a real one [11].

With Virtual Reality the focus of learning is placed in the conception of environments that allow students to interact with the computer with minimal restrictions. Virtual World are a special type of virtual reality environments and are the tools for creating highly immersive 3D interactive online environments that can be either replicas of existing physical places, or even imaginary places. They can represent places that are impossible to visit in real life due to restrictions such as cost or safety. There exist proprietary and open-source VW platforms. The main characteristics offered by Virtual Reality to education are immersion (most sensations come from the virtual environment), interactivity (free navigation, choice of referential, etc.) and manipulation (actions performed as in the real world). Virtual Reality brings together a set of characteristics that make it a unique technology as learning means

[6]:

- Virtual Reality is a powerful visualization tool to handle 3D problematic situations.
- Virtual environments allow learning situations by trial and error that might encourage students to explore a wide choice of possible solutions.
- The student is free to interact directly with the virtual objects, allowing first-hand formulation and verification of hypothesis.
- The virtual environment can offer adequate feedback, allowing students to focus their attention on specific conceptual errors.
- Virtual Reality can collect and show complex data in real time.
- The immersive nature of Virtual Reality can endow students with extra capacities to retain information.

The "ScienceSpace" project [12] is a good example of the application of the Virtual Reality in education. It consists of a series of virtual worlds designed to aid students in mastering challenging concepts in science. The project was a joint research venture and consisted of three virtual environments:

- *NewtonWorld* provides an environment for investigating the kinematics and dynamics of one-dimensional motion.
- *MaxwellWorld* supports the exploration of electrostatics, leading up to the concept of Gauss' law.

- *PaulingWorld* enables the study of molecular structures via a variety of representations.

It was one of the first efforts in the integration of virtual reality in physics education which had a wide recognition and was widely used by students and teachers.



Figure 8: Screenshot of an astrophysics seminar in a virtual world environment

3.3.5. Computer-Based Laboratories

The domain of physics is an experimental science domain and the computer based laboratories have a central role in the Physics laboratory. The richness of Computer-Based Labs and also the expressivity of the associated modeling tools could have a major impact on physics teaching and learning, and especially in students' learning and knowledge construction. These tools can be used to make the learning of aspects of Physics domain less formidable for students even for students that have lower mathematical abilities. In addition, they can be used to place more emphasis



on intuition and also to give students the ability to study and to solve complex physics problems. Students at every level of education should have an opportunity to conduct Physics experiments on various topics of the physics domain and also to participate fully and actively in learning new facts about procedures [6]. Indeed, it is widely acknowledged that hands-on participation can provide not only a strong motivation to students, but also can provide deeper understanding of science and physics procedures. In this line, computer based laboratories can provide learner controlled explorations in the Physics laboratory with real-time measurements and also give students immediate feedback by presenting data graphically in a manner they can understand. So, students can use sensors and software in order to measure and graph physical quantities and in this line the comparison of real data with simulations can enhance students learning and be a very rich pedagogical tool [6].

3.3.6. Mobile devices

The mobile media technology has become increasingly important for our daily lives as well as for technology-enhanced learning. The rapid spread and popularity of



wireless communication and mobile technologies has a strong influence on our daily lives. The spread of mobile devices is huge and a survey conducted in 2013 indicated that more than 70% of teenagers and young adults own a smartphone [13]. These numbers indicate a world-wide trend and provide quantitative evidence of the phenomenon (of which many readers are intuitively well aware) that these devices

have become part of everyday life, in particular for the young generation. With their high degree of mobility and portability, mobile devices can be used to access digital content in real-world situations indoors and outdoors, and therefore enable us to connect abstract concepts to real-world contexts for the purpose of learning [13].

In this line, an indicative example is the iMobile Physics [14] develops mobile experimental tools (METs), using smartphones and tablet PCs to conduct experiments in higher physics education, and investigates affective and cognitive effects triggered by these devices. The iMobile Physics project focuses on developing innovative experiments in physics education using smartphones and tablet PCs, on implementing them in research based learning sequences and on studying the effect of these concepts on learning and motivation in physics education from secondary level to university. An illustrative example of the use of smartphones to explore the physics of everyday phenomena is provided by the following observation made during an elevator ride.

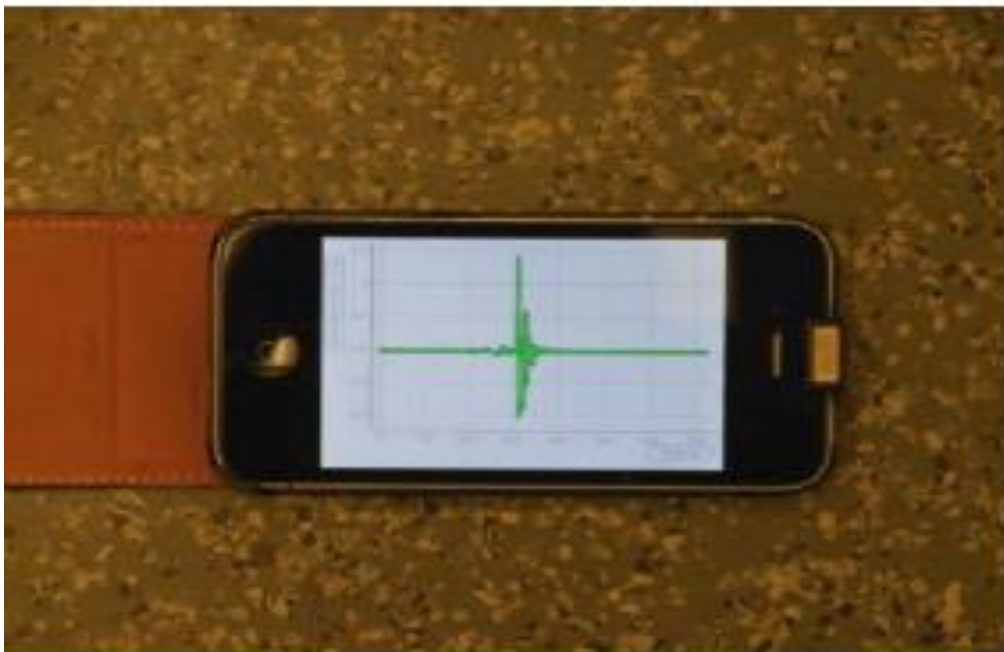


Figure 9: Simple Smartphone application



Figure 10: Experiment with object movement [22]

3.4. Physics courses and assessment

One of the most important use areas of computers and information & communication technology in physics education is that it can be applied in laboratory experiments and on difficult concepts related to the teaching of physics and provide the opportunity of straightforward teaching. What is more, data in experiments can be collected using computers as aids in laboratories and this data can be displayed simultaneously and analyzed [15]. Also, experimental procedures which are difficult to make or hard for the students to deeply understand in a real laboratory environments can become easier to illustrate and understand with the help of simulations in the context of school courses. In this way, physics courses with the

integration of advance and state of the art information and communication technologies can become more fun oriented and immersive. In this line, they can affect students' thoughts about the physics domain and most of all, their motivation and understanding significantly.

As mentioned above, in our days there are numerous information & communication applications available, that aim to stimulate students' active engagement and offer the opportunity to work under conditions that are difficult, dangerous or time-consuming to be conducted in the classroom or even the physics laboratory of the school or the educational institute. In this direction, the use of ICT applications has developed a new research field in physics education, and has the potential to greatly change the conditions under which physics teaching is being conducted [16]. From a teacher's perspective this stands both for physics teaching and also for assessment procedures in the context of his/her courses. ICT applications can provide the means for efficient, instant assessment of students' performance on test and educational procedures.

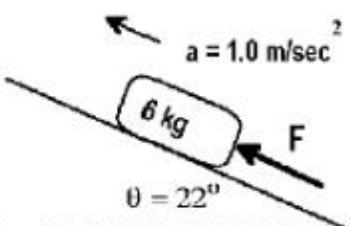
WebAssign
ncsu Info Guide Student Surveys Textbook Credits Logout

Name: Joe Student
 School: North Carolina State University
 Course: PY 001, section 00S, Fall 1998
 Teacher: Scott Bonham
 Due Date: Thursday, October 7 1999 9:00 AM EDT
 Current Date: Monday, October 4 1999 4:07 PM EDT

Example WebAssign question

You may resubmit changes in your last response on this page.
 You have made 1 submissions out of the 3 allowed.
 These are the scores for the last submission

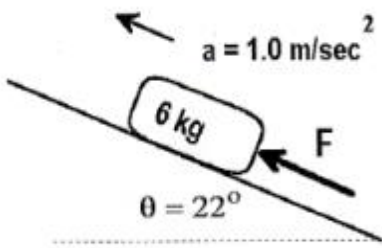
Question	1	
QID	52752	Total
Points	2	2
Bonham, Scott	1	1



1. Find the magnitude of F

- If the plane is frictionless N
- If the kinetic coefficient of friction is 0.35 N

Submit for Grading



Find the magnitude of F

- if the plane is frictionless
- if the kinetic coefficient of friction is 0.3

return to main page | return to this week's assignment

$F_{net} = ma$
 $F - mg \sin \theta = ma$
 $F = 28.02 N$

$F_{fric} = (6 kg)(1.0 m/sec^2)$
 $54.5(3) + 6 + 22.03 =$
 $= 38.78 N$

$F = F_{net} + mg \sin \theta + f$
 $= 28.02 + 22.03 + 14.75$
 $= 64.80 N$

Figure 11: Visualized assignment exercises

3.4.1. Computer simulations in physics teaching

In the context of the integration of ICT in physics education, simulations are of special importance in the teaching and learning of various physics domains. Indeed,



as pointed out above, simulations can offer new educational environments, which can enhance both teachers' instructional potentialities and also facilitate students' active learning and engagement. In addition, simulations can offer a great variety of opportunities for modeling and illustrating a wide spectrum of concepts

and processes. In this line, simulations provide a bridge between students' prior knowledge and the learning of new physical concepts, helping students develop scientific understanding through an active reformulation of their misconceptions. Specifically, educational learning environments that integrate simulations can provide students with various opportunities to [17]:

- develop their understanding about phenomena and physical laws through a process of hypothesis-making, and ideas testing;
- isolate and manipulate parameters and therefore helping them to develop an understanding of the relationships between physical concepts, variables and phenomena;
- employ a variety of representations (pictures, animation, graphs, vectors and numerical data displays) which are helpful in understanding the underlying concepts, relations and processes;
- express their representations and mental models about the physical world; and
- investigate phenomena which are difficult to experience in a classroom or lab

setting because it is extremely complex, technically difficult or dangerous, money-consuming or time-consuming, or happen too fast.

It is important to indicate that in physics knowledge is achieved by constructing models of physical phenomena, and in this direction according to [18] two types of models can be determined:

- *mental models*, which are representations of the physical phenomena constructed in the minds of students and contain a set of information about what students know (either correct or incorrect);
- *conceptual models*, which originate from mental models and are created by the cooperative activities of scientists. Students' active engagement with them is essential to overcome their conceptual obstacles and reach the scientific conceptual models.

In addition, we can distinguish between two types of computer models in physics education:

- *exploratory models*, which are constructed by experts to represent domain knowledge. Usually they are micro-worlds that simulate physical processes and laws. Such micro-worlds encourage students explore and interact with them, handle parameters and observe their results; and
- *expressive models*, which allow students express their own ideas on a domain. They provide learners with tools to define relationships between concepts, explore the consequences of those student-defined relationships and learn through an active process of representing their own models.

In our days, there is available a wide variety of educational tool and learning environments that aim to assist teachers and students and help them to present and model physical phenomena and processes or solve physics problems. In this context ICT and simulations can be powerful cognitive tools. An example case of simulations is on the topic of periodic motion as presented in next figure. The interactive nature of the simulation in the context of the system, lies on the questions asked by the teacher to refresh the student's knowledge of Hooke's law such as for example, "What do you think that would happen if you hang the mass from the spring", or "What will happen if you now hang a larger mass? Should the spring stretch the same, more, less?"

Students can check their predictions using the simulation (next figure) and compare results. With guidance from the teacher, the student can infer or simply remember Hooke's law.

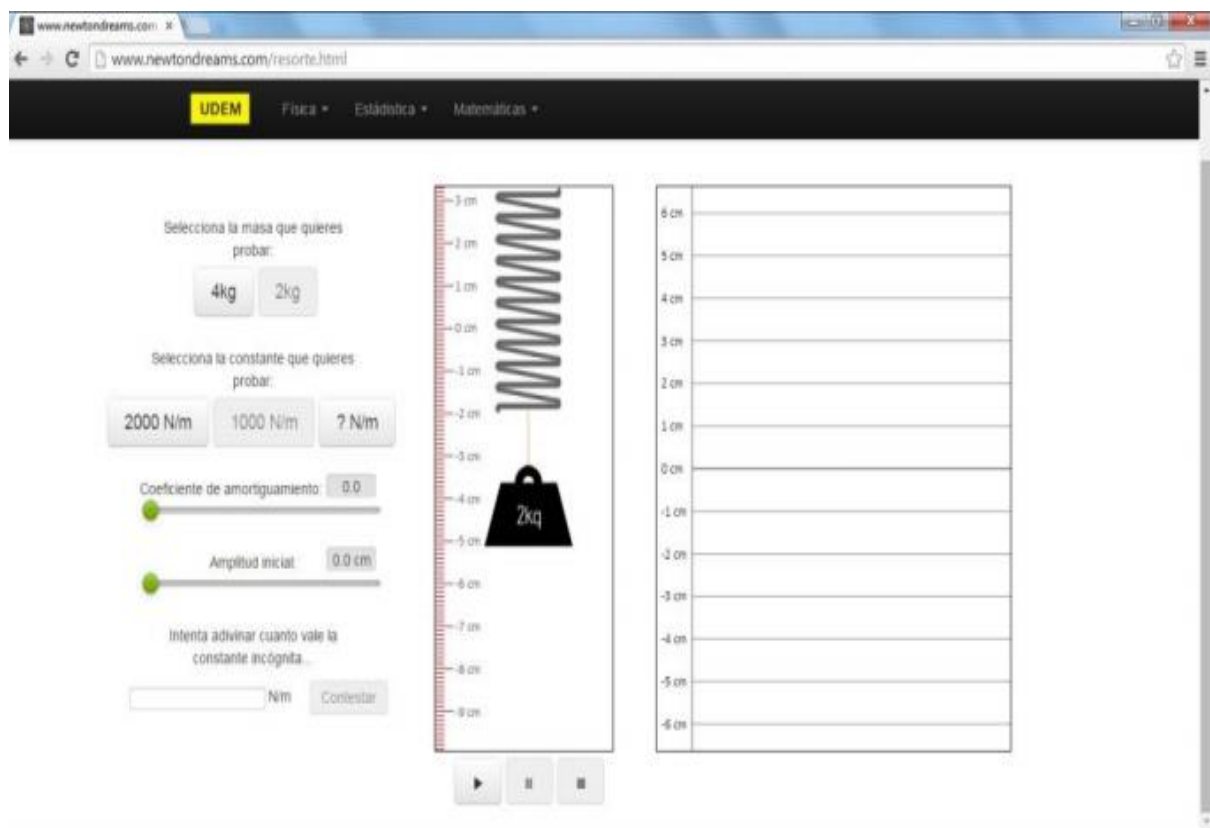


Figure 12: Simulation of a mass-spring in equilibrium

After that, the student can proceed to take the mass away from equilibrium, and examine its behaviour.

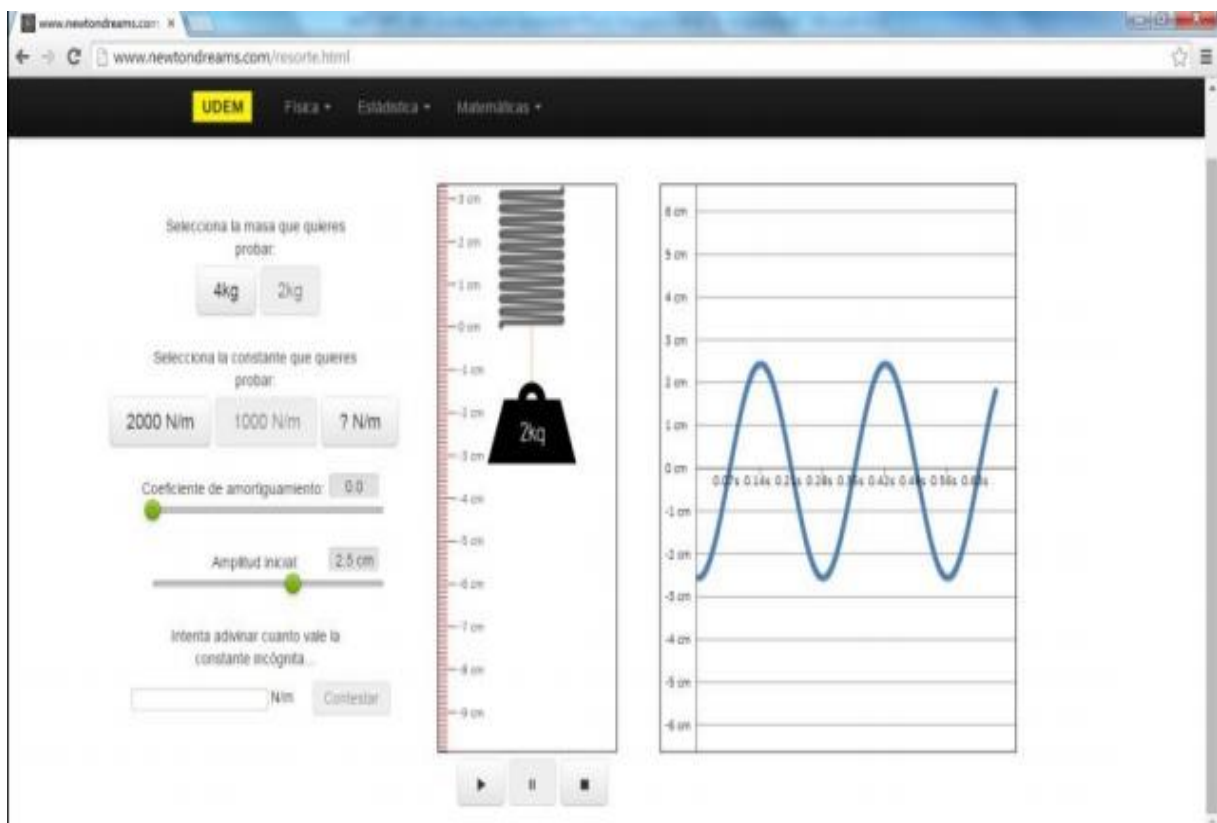


Figure 13: Simulation of a mass-spring in motion

3.4.2. Simulating Newtonian mechanics through Interactive Physics

Interactive Physics (<http://www.design-simulation.com/ip/>) is a two-dimensional virtual physics laboratory that simulates fundamental principles of Newtonian mechanics. The simulation engine needs no programming. Simulations produced by the system are based on two numerical analysis methods, a fast (Euler) and an accurate one (Kutta-Merson) and present a realistic movie of the objects' evolution on the screen. A series of physical quantities (velocity, acceleration, momentum, angular momentum, kinetic energy, etc.) can be measured in vector, digital, graphical or bar form, while the simulation is executed. Example cases are presented in the next figures.

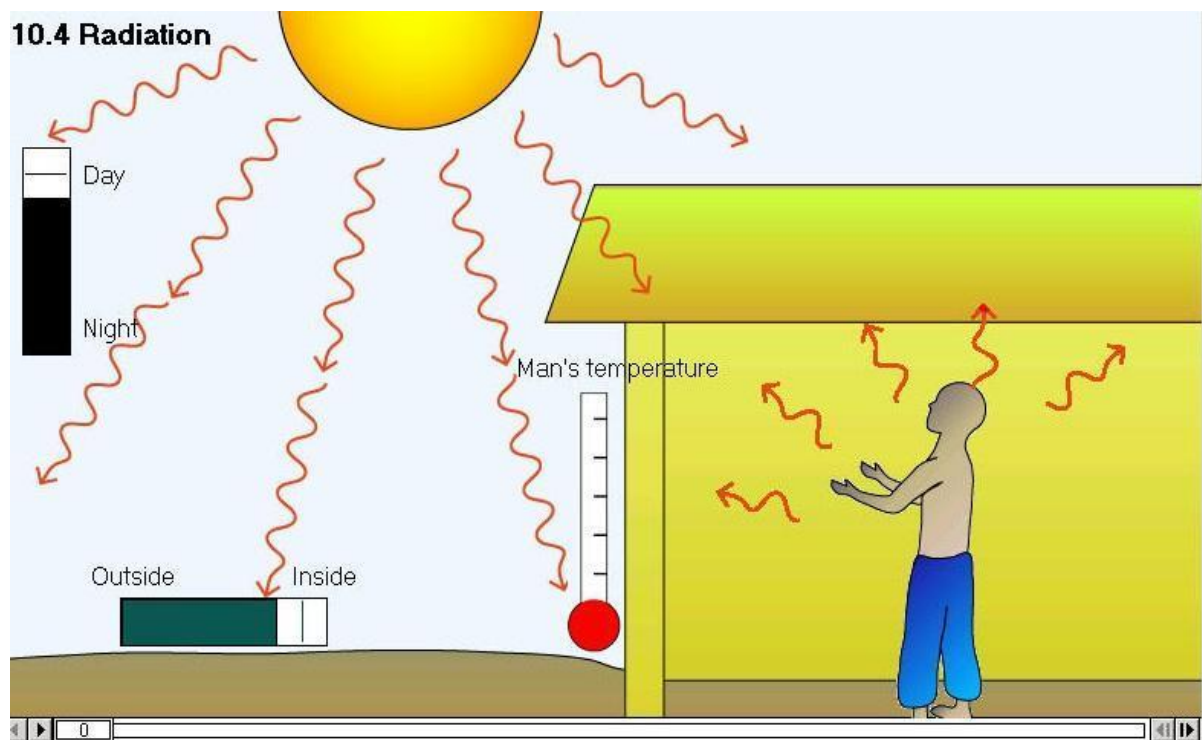


Figure 14: Interactive physics radiation topic illustration

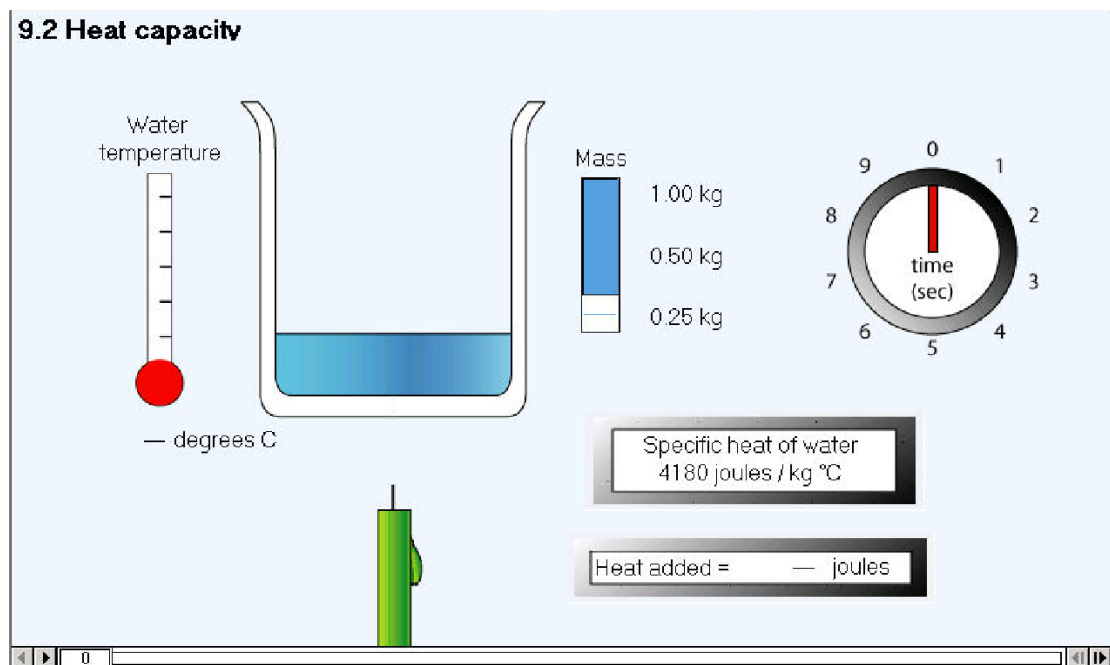


Figure 15: Interactive physics heat capacity topic illustration

The environment of Interactive Physics provides an easy to use interface through a series of interaction buttons and objects like [17]:

- buttons, that offers students the opportunity to add commands directly to the working space without the need to invoke dialog boxes
- controls, that allow students adjust simulation parameters before and during a simulation's execution; and meters, that allow measurement of the relevant physical quantities in digital, graphical or bar form. Data from any meter can be exported to other applications, such as spreadsheets or graphics packages.

In the next figure an example case is illustrated. It simulates a ball falling freely from a given height in the earth's gravitational field. The various frames that project successive positions of the ball are also presented.

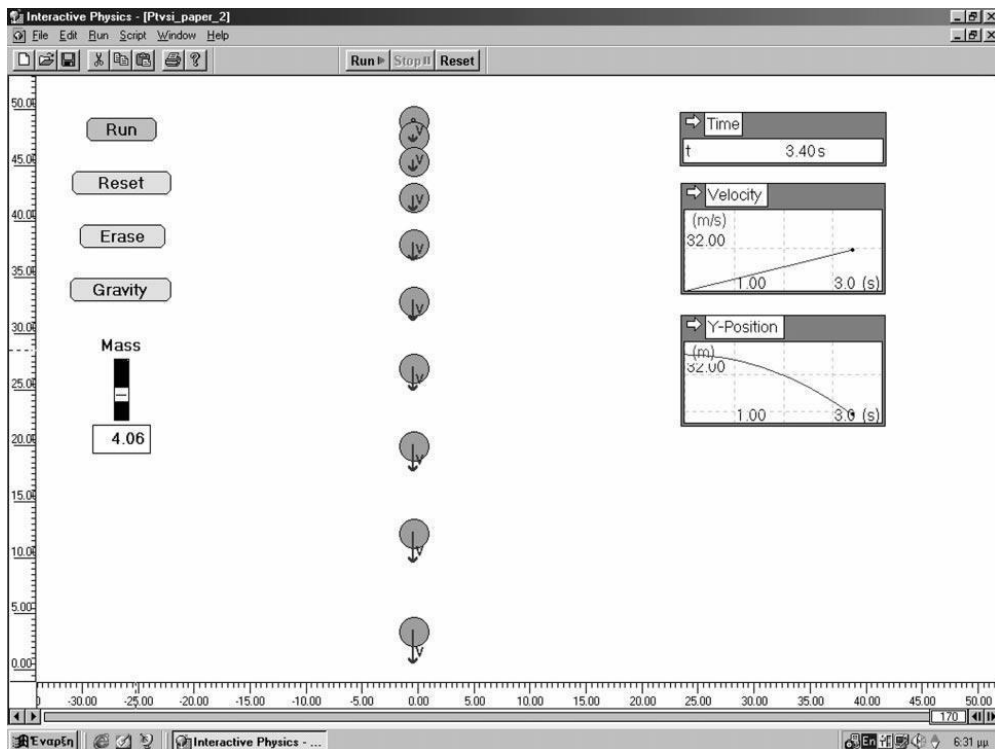


Figure 16: Interactive simulation of gravity force.

Interactive Physics can be used in Physics teaching and learning as:

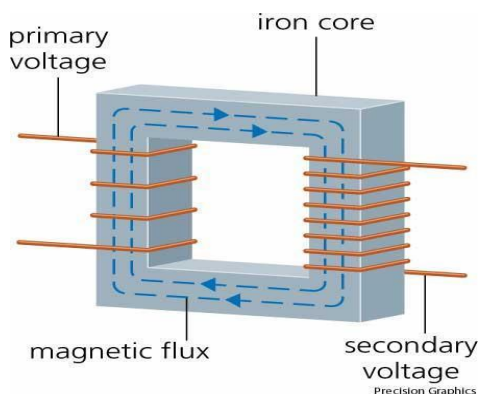
- a virtual Physics laboratory for modeling and presenting phenomena and processes; and
- an expressive environment where students can demonstrate their ideas and mental models, make predictions, derive physical laws and solve problems.

It is widely acknowledged by the education community that experimenting on trajectory motion in school physics laboratories is very difficult since it usually demands students' adequate experimental skills, as well as skills on using accurately a wide spectrum of tools [17]. The simulations are an alternative approach offering distinct teaching and pedagogical advantages. Students can do their experimental studies as many times as they want in order to understand in detail the topics they

study.

3.5. Simulations and multimedia on physics topics

3.5.1. Electromagnetism



Electromagnetism constitutes an important topic of physics domain which is part of the curricula of all the levels of education for elementary to university level. Simulations and multimedia content offer various opportunities for better teaching and learning the challenging topic of electromagnetism. Various experimental studies

and simulations can be modeled in educational environments. These experiments based on the characteristics of the topic, can be complemented by engaging 2D and 3D visualizations and simulations of the various aspects of electromagnetism under study. The simulations can allow students to make abstract ideas concrete. More specifically, students gain insight into various concepts by watching in detail. Such animations allow students to develop intuition regarding connections between the forces transmitted by electromagnetic fields and more tangible forces, such as those exerted by rubber bands or strings [19].

In next Figure an example of an interactive simulation that corresponds to a Faraday's Law desktop experiment is presented. The aim of the simulation is to assist students in studying various aspects of electricity. In the concept presented in the figure students can let a loop of wire fall along the axis of a magnet and observes the resultant eddy current in the loop, as predicted by Faraday's Law. In the Java applet, the student can perform the same experiment virtually and study both the current and the magnetic field that it generates.

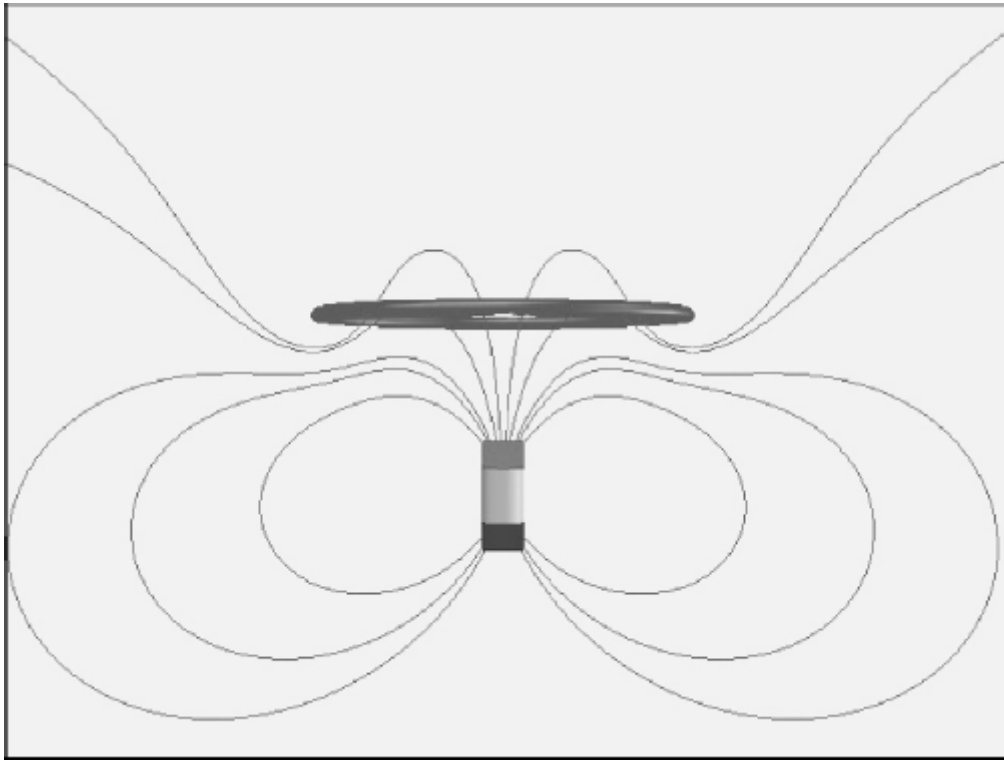


Figure 17: A Java applet showing a conducting non-magnetic loop of wire falling under gravity past a fixed permanent magnet

In the simulation, students can calculate the motion of the falling wire loop and also plot the magnetic field lines of both the magnet and the eddy current in the loop. Using sliders and text fields at the bottom of the screen, a student can change two parameters in the simulation. The first, “Resistance,” is proportional to the resistance of the wire loop divided by its inductance, while the second, “Dipole Moment/Mass,” is proportional to the dipole moment of the magnet divided by the square root of the mass of the magnet.

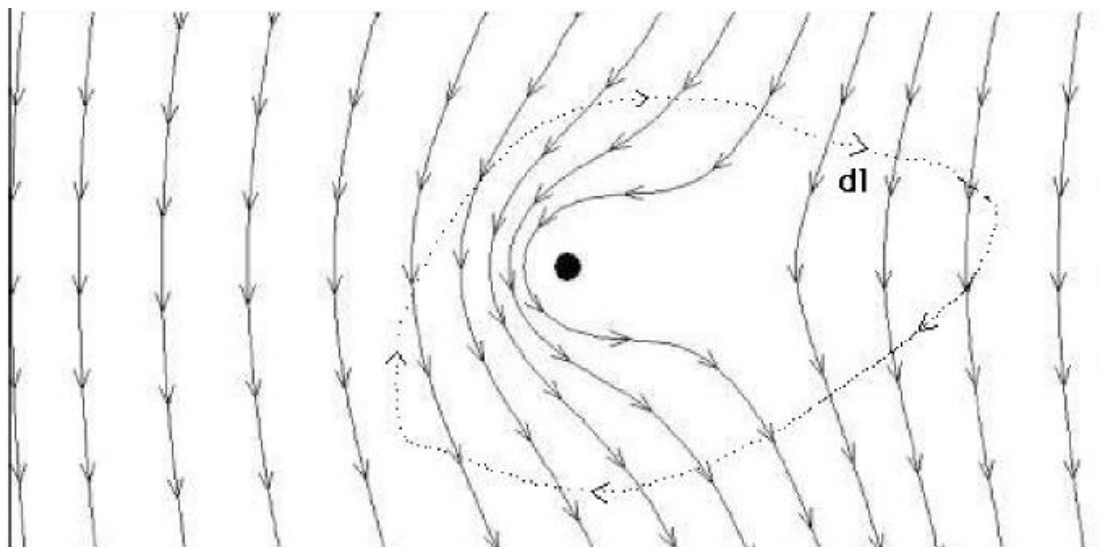


Figure 18: Illustration of electromagnetic fields

3.5.2. Quantum Physics

Multimedia are quite suitable tools for assisting students in learning. Below, a number of indicative and popular example cases on the use of multimedia in physics education are presented.

QUVIS:

<http://www.st-andrews.ac.uk/physics/quvis/>

<http://quantumphysics.iop.org/>

This is an extensive collection of Flash and HTML5-based tutorials with interactive simulations of quantum systems and step-by-step explanations of the concepts involved. The presentations have very attractive graphics and clear explanations, with the step-by-step tutorials particularly noteworthy for helping students focus on the important physics. The Physics Simulations take students through the traditional sequence used in most quantum courses, from the concepts of probability to perturbations and Fermi and Bose statistics. The New Quantum Sims are used as the multimedia resources in the IOP Quantum Physics web site. This work focuses

on quantum optics and quantum information theory, with many simulations using Stern- Gerlach experiments as their example. Almost all of the items include student activities and didactic recommendations, with the IOP site providing extensive tutorial and reference resources supplemented by the simulations. The translation of this material to HTML5 for use on all platforms is of particular note. An excellent example of the QUVIS materials is the Hidden Variables simulation. This is one of the culminations of the entire collection. It shows the virtual experiment and the different results of quantum and hidden-variable theories [20].

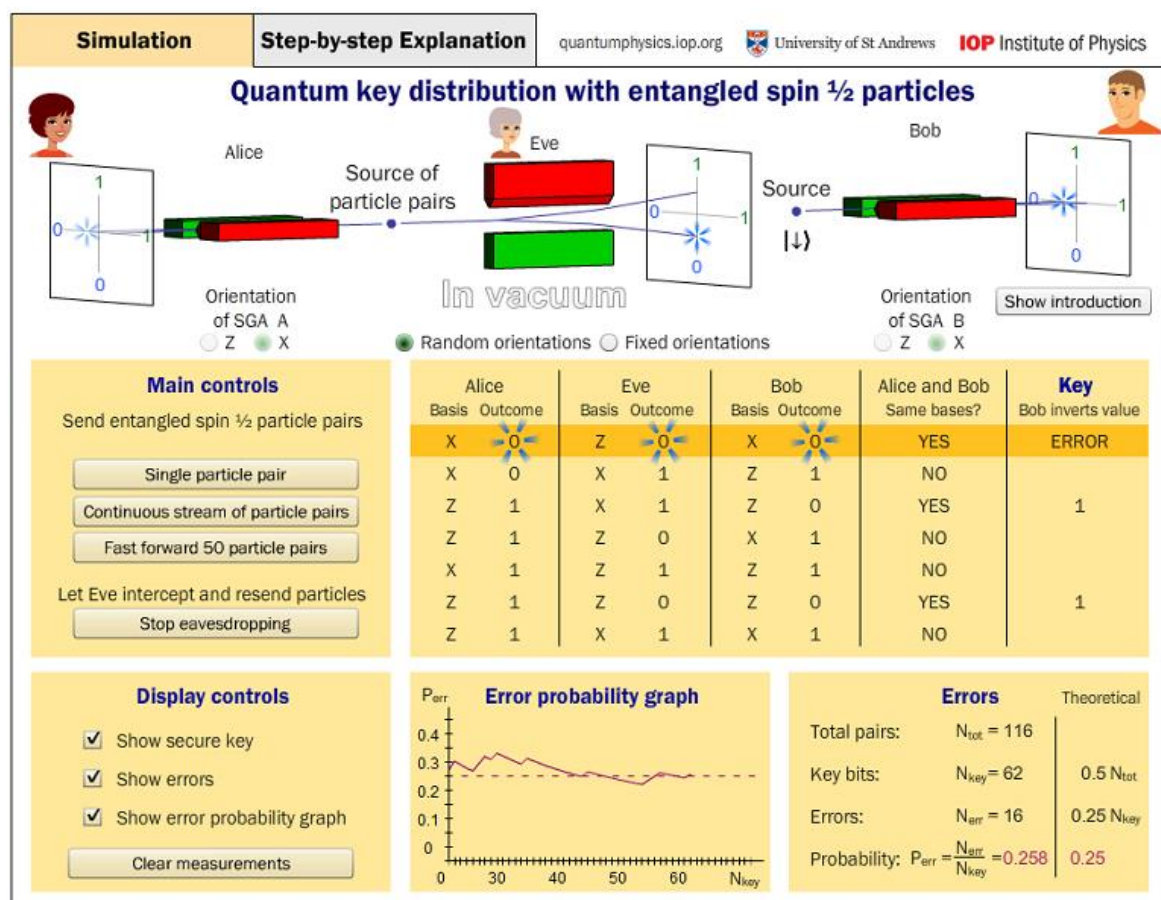


Figure 19: QUVIS: Quantum mechanics vs Hidden Variables

PhET:

<http://phet.colorado.edu/en/simulations/category/physics/quantum-phenomena>

This is a collection of easy-to-run simulations suitable for middle-school (a few), high school, and college. These simulations are highly interactive and open environments with drag-and-slide user interfaces and game-like immediate feedback. The simulations can be used in a range of different ways, homework, prelabs, and in-class explorations. Most of the simulations have recommendations for instructors, including learning goals and example activities. General recommendations for using simulations are also available. The reviewers also emphasized the fact that the PhET materials are available in a wide range of languages. The PhET simulations are carefully researched and designed for interactivity and student learning. Many of these simulations are connected to “modern physics” experiments, such as lasers, the photoelectric effect, Stern-Gerlach, and Davisson-Germer experiments rather than “pure quantum theory”. The Teacher Tips provide some information about the models and approximations used in the simulations, as well as student understanding of the topic and details about operation of the simulation. An excellent example of a simulation of standard quantum problems is the Quantum Bound State [20]. A noteworthy example of a virtual experiment is the Photoelectric Effect.

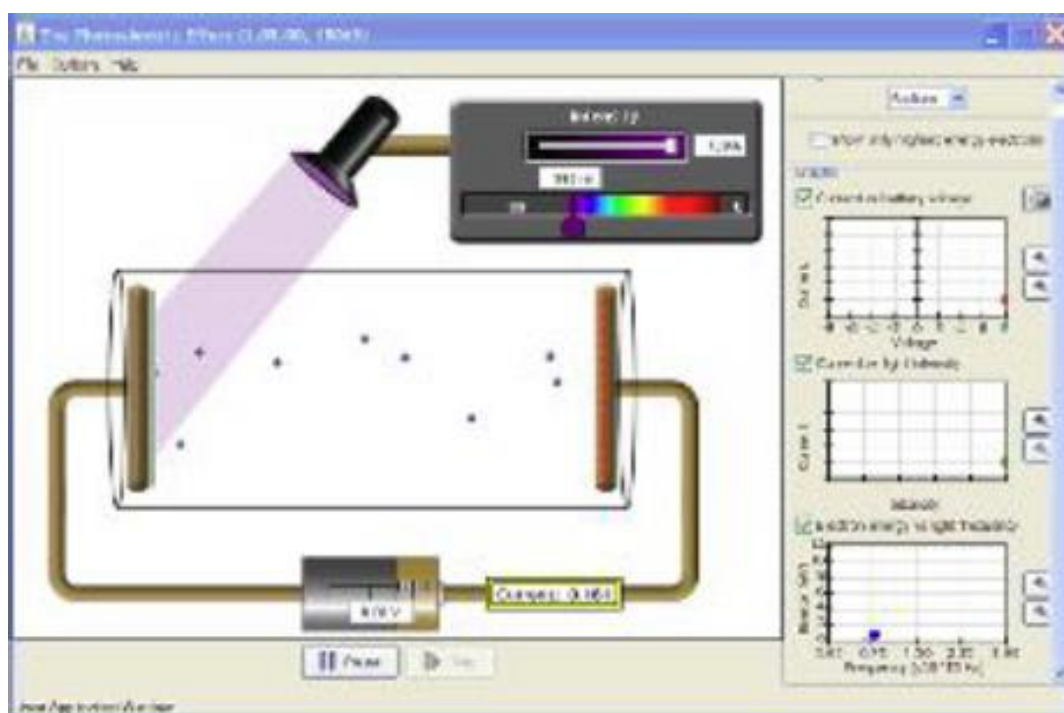


Figure 20: PhET Photoelectric Effect Simulation

Physlet Quantum Physics:

<http://www.compadre.org/pqp/>

This online textbook supplement of interactive illustrations and problems covers topics ranging from experiments demonstrating quantum phenomena, through standard bound and scattering state physics, to applications in atomic, nuclear, and statistical physics. Users can control states, energy levels, potentials, etc. and observe the resultant changes. Students may explore quantum systems for themselves with the help of guiding questions that range from qualitative ranking tasks to quantitative calculations.

One reviewer felt that the Physlet Quantum Physics simulations' graphics are somewhat dated and simple. They also noted that words such as " $\psi^*(x) \cdot \psi(x)$ " are used in simulations rather than Greek letters. The physics behind an animation of a

scattering state needs to be understood to answer questions about energy and potentials [20].

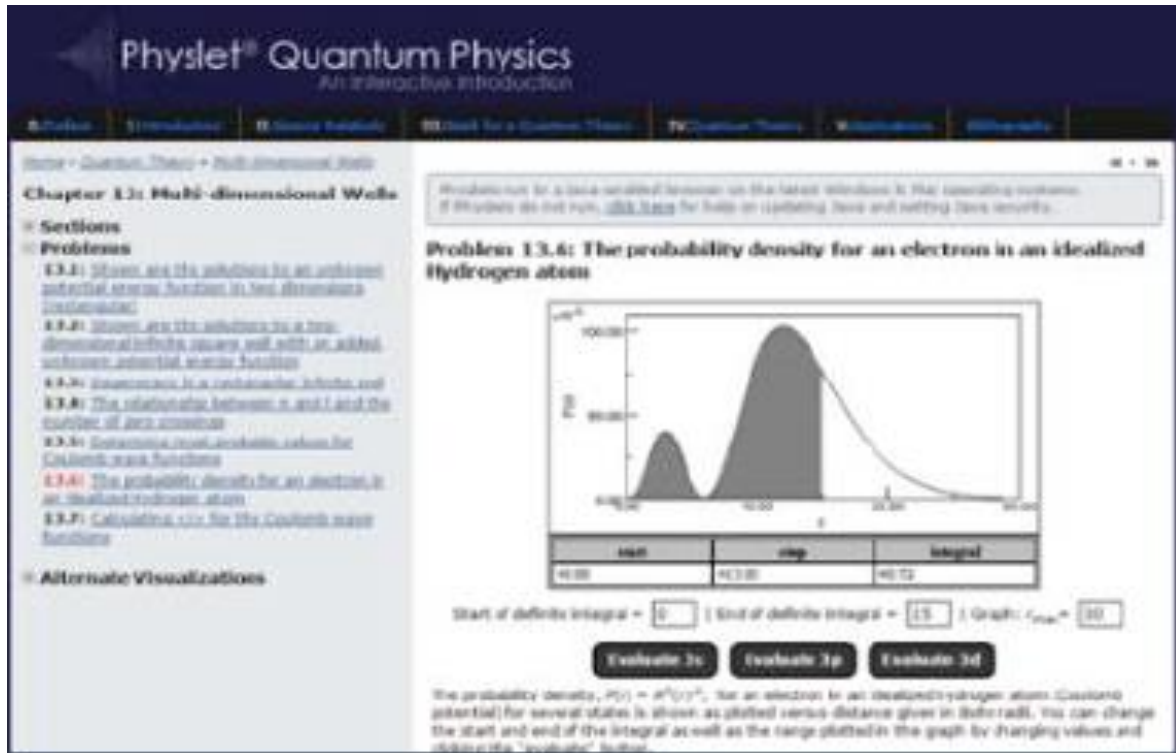


Figure 21: Physlet Physics Exploration of Probability Density

Quantum Lab:

<http://www.didaktik.physik.uni-erlangen.de/quantumlab/english/index.html>

This is a set of Interactive Screen Experiments covering quantum optics. Each of the experiments are illustrated with images of real experiments. Real data is provided when the experiments are “turned on”. Quantum entanglement, quantum cryptography, and other quantum information experiments are included along with more basic examples. This content can be used as pre-labs for schools with the facilities to perform quantum optical experiments, or as entirely virtual labs. Each experiment is well described, with motivating introductions and explanations of the

observations. Reviewers noted that some design and layout of the controls is problematic, with control placement and design changing in different experiments. The ability to zoom in on parts of the experiment is a plus. Some of the data is in German. To start exploring this material, the Existence Photon experiment can give an indication of its interface and display of real optics experiments [20]. A more sophisticated experiment, such as Entanglement, will show how data is displayed.

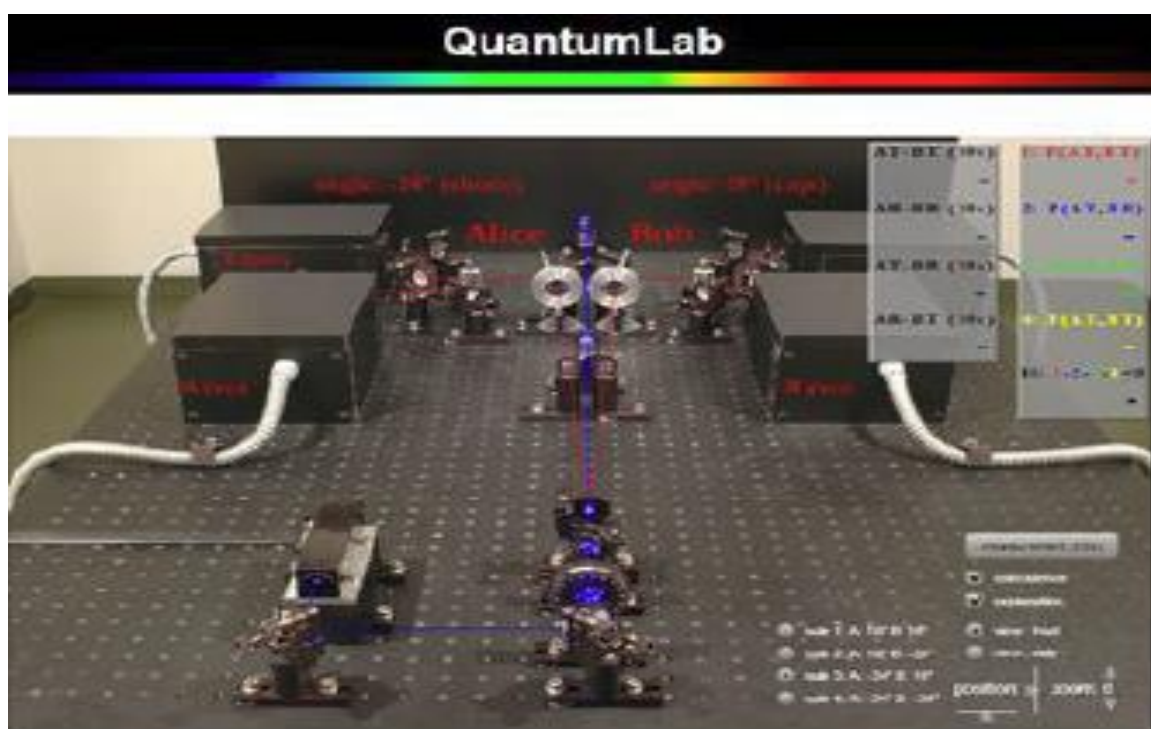


Figure 22: QuantumLab Entanglement & Non-locality

Spins Physics:

http://www.physics.orst.edu/~mcintyre/ph425/spins/index_SPINS_OSP.html,
<http://www.compadre.org/osp/items/detail.cfm?ID=7329>

The Oregon State University SPINS web site provides a complete set of course materials (worksheets, virtual labs, in-class activities, and homework) for a quantum mechanics course that begins by studying spin systems. The Open Source Physics

(OSP) package integrates these tutorials with simulations for student investigations. The software allows students to drag, drop, and connect elements. The interface allows students to create many different experiments on quantum dynamics and quantum measurement. The simulation is simple to use, but is rather schematic so students may not understand precisely what is being observed. The software can be used for different sorts of learning activities. This work is based on the “SPINS” software package that has been developed over the years by several different programmers. A good example of the Spins tutorial material can be found under “Exercises” and the tab for “Spin Precession” at the bottom of the page. This series simulations are arranged to help students understand the quantum rotation of spins in magnetic fields [20].

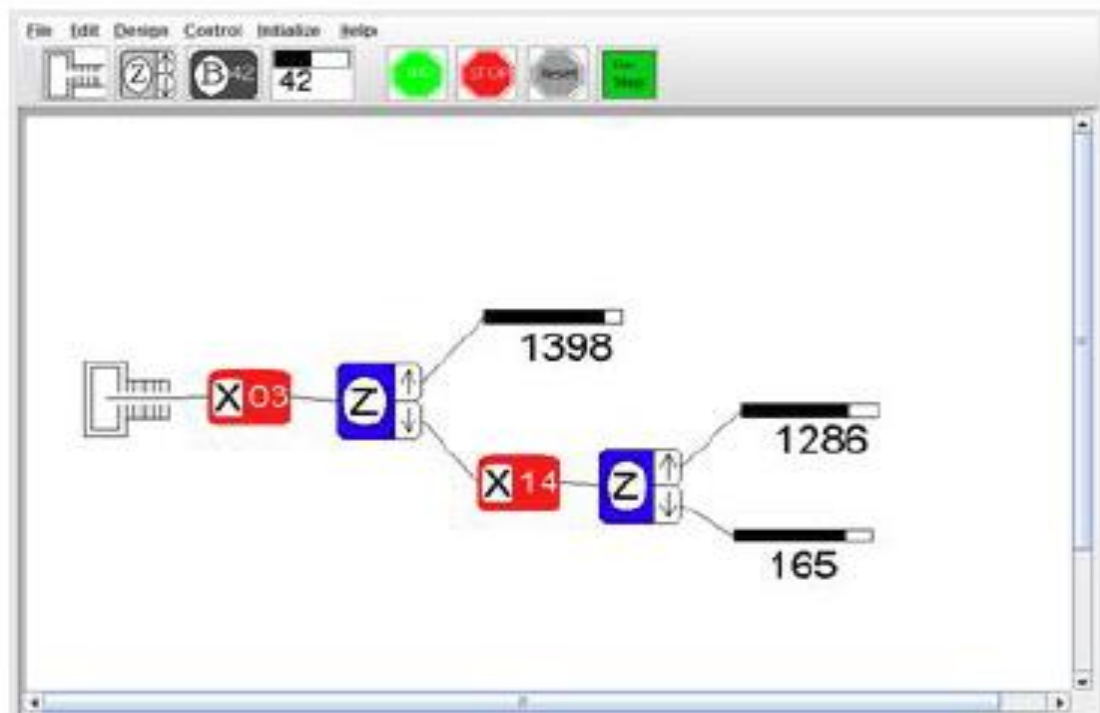


Figure 23: Spins Stern-Gerlach Simulation

Falstad Quantum:

<http://www.falstad.com/mathphysics.html>

This well-known web site provides good qualitative illustrations of quantum mechanics and complex systems. Some of the physics topics simulated are unique. Of note are the dynamic quantum transitions applets for a bound state interacting with a classical oscillating electric field. This material, however, is somewhat limited in the topics covered and lacks didactic materials or recommendations. Rather basic explanations about the simulations are provided, most covering only how to run the simulation. Details about the physical models and simulation methods use are not available for many of these programs.

One excellent example of the Falstad work is the Atomic Dipole Transitions applet. It considers the dynamics of an atom interacting with different types of electric field. The Rigid Rotator and the Square Well applets illustrate the displays provided.

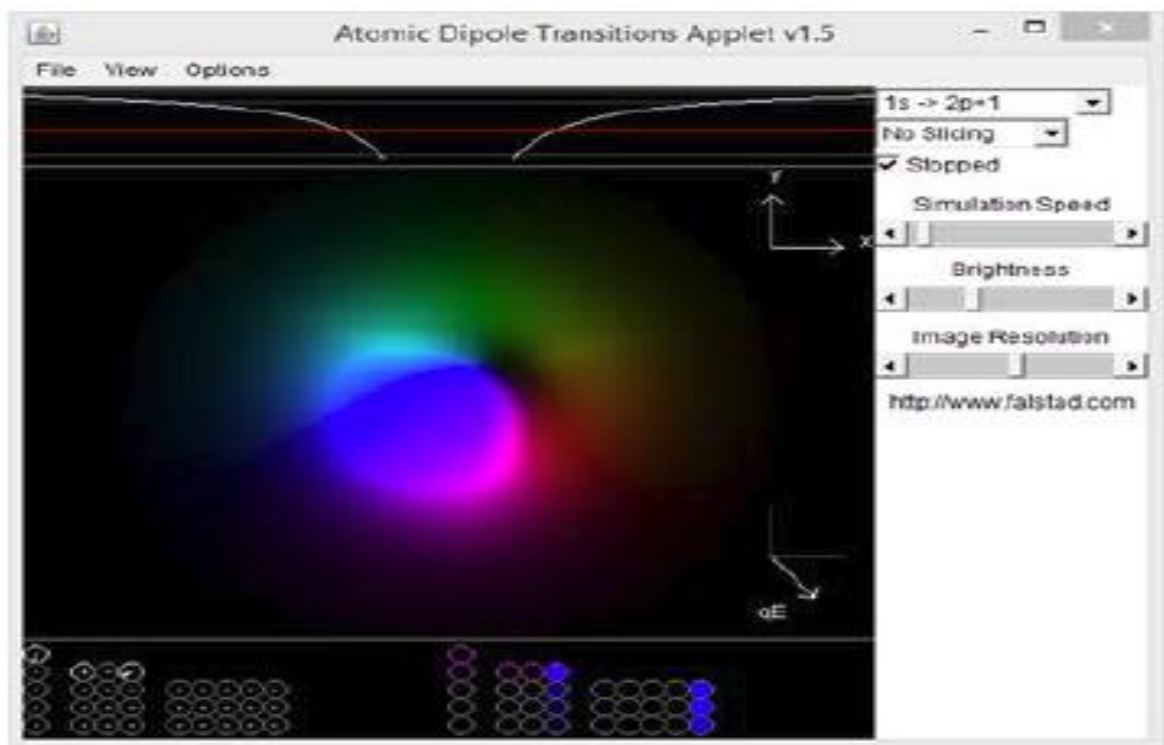


Figure 24: Paul Falstad Atomic Dipole Transition

Quantum Mechanics:

<http://www.embd.be/quantummechanics/default.html>

This combination of text and videos provides a multimedia tutorial on quantum mechanics. Topics include wave motion and interference, Aharonov-Bohm effect, and identical particles. The sequence of topics leads the reader through important aspects of quantum physics. The video simulations are somewhat dated and lower resolution, and are not interactive. One reviewer felt that there could be more questions and tasks for the student. For those interested in this work, the Aharonov-Bohm section is a rather unique study of this physics.

Excited States and Photons:

<http://concord.org/stem-resources/excited-states-and-photons>

This material is a secondary school level introduction to the interaction of light and matter, including quantization of energy. The connection between atomic energy levels and emitted photons is stressed. Multiple choice and free-response questions throughout provide tutorial guidance. The materials are easy to follow and the goals and learning approaches are clear. The coordinated use of pictures, animations, words, and interactive simulations was noted by one reviewer. This could also be used in conceptual physics classes at the college level. An example of the tutorial nature of this work is the second half of the activity where atomic energy levels, photon colour, and kinetic energy are connected.

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